Off-Farm Work Decisions of Husbands and Wives: Joint Decision Making

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Abstract
When a husband or (and) wife in a farm household do not participate in off-farm work, optimal hours of off-farm work for one or both of them will be at the boundary of one or two non-negativity constraints. These boundary solutions have important implications for household choices because when they occur, the marginal value of an individual's time is no longer determined by the external labor market. It is determined internally to the household by weighing the demand for an individual's on-farm labor and home time against his (her) time endowment. Each time that a binding non-negativity constraint is encountered, the economic structure—variables to be included and coefficients—of household choice functions is changed.

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Off-Farm Work Decisions of Husbands and Wives: Joint Decision Making

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When a husband or (and) wife in a farm household do not participate in off-farm work, optimal hours of off-farm work for one or both of them will be at the boundary of one or two non-negativity constraints. These boundary solutions have important implications for household choices because when they occur, the marginal value of an individual's time is no longer determined by the external labor market. It is determined internally to the household by weighing the demand for an individual's on-farm labor and home time against his (her) time endowment. Each time that a binding non-negativity constraint is encountered, the economic structure—variables to be included and coefficients—of household choice functions is changed.

The objective of this paper is to propose and fit a recursive multiple-equation econometric model of the joint decisions for off-farm work of a husband and wife in farm households where endogenous switching of the econometric structure occurs whenever binding non-negativity constraints occur. In implementing this conceptually appealing framework, econometric problems arise due to small subsample sizes and near-multicollinearity. The final estimates of the off-farm labor supply equations are obtained by applying ridge regression to multiple Tobit-type unconditional off-farm labor supply functions for husbands and wives.

The model presented here differs significantly from earlier econometric studies of off-farm work of farm household members. The papers by Huffman (1980) and Sumner (1982) consider only the off-farm work of farmers. Barnum
and Squires (1979) have only one household time endowment in their model. They aggregate a household's own and hired farm labor together and assume that the external labor market always determines the marginal value of human time. Rosenzweig (1980) considers two types of labor, male and female, but he does not take full account of changes in the structure of wage labor supply functions when non-negativity constraints are encountered.

In section one, decisions on husband's and wife's off-farm work are considered in a model of agricultural household optimization where decisions on their time allocation are made jointly with other consumption and farm production decisions. The econometric model is presented in section two. Section three describes the data and discusses the empirical estimates of equations explaining off-farm work participation, off-farm labor demand or wage offers, and off-farm labor supply for husbands and wives. Conclusions are presented in the final section.
A Model of Time Allocation

The labor supply decisions of husbands and wives in farm households can be summarized in an optimizing model which permits dual employment on their farm and at off-farm jobs. The model presented here, which guides the empirical analysis, is similar to ones presented in Huffman (1973, 1980), Rosenzweig (1980), Sumner (1982) and Strauss (1986). The decision unit is a single-family farm household; and to simplify the analysis, the time allocation of only two adult household members, the husband and wife, are considered. Husband's and wife's time are assumed to be heterogenous and, therefore, must be indexed separately. Each individual receives an endowment of time each period which the household makes plans to allocate among work on their farm, work off their farm, and to home time. Home time is a residual category that includes mainly household work and leisure. An individual's hours of off-farm work may be zero, i.e., a nonnegativity constraint is implied. The allocation of husband's and wife's time are summarized as:

\[ T = T_f + T_m + T_h, \quad T_m > 0 \]

where \( T \) is the time endowment, \( T_f \) is farm labor, \( T_m \) is market or off-farm labor, and \( T_h \) is home time.

The husband and wife may work on their farm and at off-farm jobs to obtain income to spend on the market-goods component of consumption (and on investment goods). The farm household is assumed to be competitive in output and input markets. It receives cash income from net farm income \( (P_f Y_f - W_f X_f) \) and other household income \( (V_h) \), and possibly from off-farm wage work \( (W_m T_m) \), and income is spent on goods for consumption \( (Y_h) \):

\[ W_m T_m + P_f Y_f - W_f X_f + V_h = P_h Y_h \]

where \( P_f \) is the price vector for farm products \( (Y_f) \); \( W_f X_f \) is the outlay on
purchased farm inputs, and \( P_h \) is the price vector for consumption goods \( Y_h \).

In general, commuting expenses to off-farm work depend on the amount of off-farm work and commuting distance \( (M_m) \), i.e., \( C(T_m, M_m) \). To simplify, marginal and average commuting cost per unit \( T_m \) are assumed to be equal and to depend only on commuting distance, i.e., \( C_m = C_m(M_m) \). The wage rate net of commuting cost is \( W'_m = W_m - C_m \).

The off-farm labor demand or wage-offer equations facing husbands and wives are assumed to depend on their marketable human capital \( (H_m) \), local labor market characteristics \( (L_m) \) and job characteristics \( (Z_m) \) but are assumed to be independent of their hours worked during the current period. The latter assumption may be a reasonable approximation and it simplifies the resulting empirical model. The market labor demand or off-farm wage functions are summarized in vector form as:

\[
(3) \quad W_m = W_m(H_m, L_m, Z_m).
\]

The expectation is that increasing marketable human skills, e.g., formal schooling, vocational training, and experience shifts the wage offer or labor demand curve faced by an individual upward. Local labor-market conditions affect wage offers when workers and firms are immobile. Land rental and ownership opportunities are expected to be a source of reduced labor mobility in rural labor markets.

The farm business is assumed to produce and sell one farm output \( (Y_f) \). Variable inputs in farm production are husband’s and wife’s farm labor \( (T_f) \) and purchased inputs \( (X_f) \), including labor hired from other households. Farm labor supplied from outside the farm household is assumed to be heterogeneous to household supplied labor because of different entrepreneurial skills. The efficiency of farm production is assumed to depend on human
capital of the husband and wife \( (H) \), e.g., general schooling, farming experience, and on other farm-specific characteristics \( (Z) \), e.g., length of growing season, precipitation, soil characteristics. The technology of farm production is represented by the following concave production function:

\[
Y_F = F(T_F, X_F; H, Z_F).
\]

The production function (4) is substituted into the income constraint (2) to obtain a new cash income constraint:

\[
W_T + P_FF(T_F, X_F; H, Z_F) - W_XF + V_H - P_YF = 0.
\]

Household members' welfare is assumed to be summarized in a single, hybrid household-utility function. This hybrid function results from substituting a household production function into a standard ordinal household-utility function (Pollak and Wachter 1975). Household utility is assumed to depend on the inputs of home time of the husband and wife \( (T_h) \) and of goods purchased for direct or indirect consumption \( (Y_h) \):

\[
U = U(T_h, Y_h; H_h, Z_h), \quad \partial U/\partial \Omega > 0, \quad \partial^2 U/\partial \Omega^2 < 0, \quad \Omega = T_h, Y_h, H_h.
\]

Thus, \( T_h \) and \( Y_h \) are assumed to be objects of current choice, but household utility also depends on human capital variables that affect the efficiency of household production \( (H) \), e.g., schooling, experience or age; and other household characteristics \( (Z) \), e.g., number of children in the household, commuting distance from the residence to shopping, recreating, and schooling centers.

The key household decision or choice variables in this study are \( T_m \), the amount of husband's and wife's time supplied to off-farm work, but these variables are determined jointly with \( X_F, Y_F, T_F, Y_H, \) and \( T_h \). The conditions for optimal choices are obtained by maximizing equation (6) subject to resource
constraints imposed by equations (1), including the nonnegativity constraint for off-farm work, and (5). Assuming an interior solution for all choices except $T_m$, the first-order conditions for a constrained maximum are:

(7) $\lambda [P_f P_{X_f} - W_f] = 0$,

(8) $\lambda P_f P_{T_f} - \gamma = 0$,

(9) $\lambda W'_m - \gamma < 0$, $T_m > 0$, $T_m (\lambda W'_m - \gamma) = 0$,

(10) $U_{T_h} - \gamma = 0$,

(11) $U_{Y_h} - \lambda P_h = 0$,

(12) $T - T_f - T_m - T_h = 0$,

(13) $W'_m T_m - P_f F(T_f, X_f, H_f, Z_f) - W_f X_f + V_h - P_h X_h = 0$,

where $\gamma$ and $\lambda$ are Lagrange multipliers for marginal utility of time, and income, respectively, and $U_j$ and $F_j$ are partial derivatives of the functions $U$ and $F$, respectively.

Equations (8)-(10) give conditions that must be met for optimal time allocation by a husband and wife. Both members are assumed to always have optimal positive hours of farm and home time, i.e., equations (8) and (10) are equalities. Equation (9) provides the optimality condition for off-farm work. If $\lambda W'_m - \gamma$ or $W'_m - \gamma/\lambda < 0$, then the marginal value of an individual's home time or farm labor exceeds his (her) wage offer, net of commuting cost, for off-farm work, and optimal hours of off-farm work are zero, i.e., $T_m^* = 0$. If $\lambda W'_m - \gamma$ or $W'_m - \gamma/\lambda = 0$, then an individual's off-farm wage, net of commuting cost, equals the marginal value of his (her) home time or farm labor and optimal hours of off-farm work may be positive. Furthermore, when farm
and off-farm work requires specialized skills (e.g., formal or on-the-job training) and households are risk neutral, individuals tend to specialize in one major type of work activity (Becker 1981).

When an interior solution for $T_m$ occurs, the off-farm labor market determines the marginal value of husband's and wife's time, i.e., $\gamma/\lambda = W'_m$. Equations (7)-(9) are then the conditions for profit maximizing farm input usage, and they can be solved independently of the rest of the equations to obtain the optimal choices (*) on farm inputs, including the demand functions for husband's and wife's farm labor:

$$T^*_f = D_{T_f}(W'_m, W'_f, P'_f, H'_f, Z'_f).$$

To obtain the demand functions for husband's and wife's home time, all of the information contained in equations (7)-(13) are required:

$$T^*_h = D_{T_h}(W'_m, W'_f, P'_f, P'_h, V'_h, H'_f, Z'_f, H'_h, Z'_h).$$

The off-farm labor demand functions can be derived from the human time constraint (1) and the demand functions for farm (14) and home time (15):

$$T^*_m = T - T^*_f - T^*_h = S_{T_m}(W'_m, W'_f, P'_f, P'_h, V'_h, H'_f, Z'_f, H'_h, Z'_h).$$

Equation (16) explains household decisions on off-farm work when interior solutions occur for all choices.

Optimal hours of off-farm work for either the husband or wife or for both of them may be at the boundary of the nonnegativity constraint, and one or both of them do not participate in off-farm wage work. These boundary solutions have important implications for other household choices because when they occur, the marginal value of an individual's time is no longer determined by the external labor market. It is determined internally to the household by
weighing the demand for an individual's farm labor and home time against his (her) time endowment. In this model, if the husband and (or) wife do not participate in off-farm wage work, farm input decisions cannot be separated from household consumption decisions and the off-farm wage rate for the non-participant is no longer a determinate of optimal household choices for $T_h$, $T_f$, $Y_h$ and $X_f$. Thus, each time that the boundary of a nonnegativity constraint is encountered, the economic structure—variables included and coefficients—of household choice functions are changed. Also, see Lee and Pitt, and Wales and Woodland.

Selected comparative-static results are summarized. If home time is a normal good, an increase in household other income ($V_h$) increases or shift rightward the demand for an individual's home hours. For an off-farm work participant, his (her) farm hours remain unchanged. Thus, his (her) off-farm labor supply curve is shifted leftward by an increase in $V_h$. If, however, the increase in home time is large, optimal hours of his (her) off-farm work could be reduced to zero. For a nonparticipant, all increases in an individual's home time are accompanied by an equal hourly reduction in farm work.

The wage elasticity of off-farm hours can be positive, negative, or zero. For a wage-work participant whose home time is a normal good, an exogenous increase in his (her) off-farm wage has two opposing effects on his (her) off-farm labor supply. First, a pure substitution effect, holding utility constant, decreases the demand for his home time, and, second, an income effect increases the quantity demanded of his home time. Thus, these two effects pull in opposite directions on off-farm hours. An exogenous rise in the wage rate of a wage-work participant increases the opportunity cost of farm hours and is expected to reduce his (her) farm hours. For a nonparticipant, a rise in the off-farm wage rate increases the probability that he
(she) becomes an off-farm work participant. The expected effects of accumulated human capital and other variables on off-farm and farm hours are generally a priori uncertain in direction. When one of the human capital variables increases, it may increase the efficiency of farm and (or) household production but more information is required about the nature of the change before predictions can be made. This does not mean that some of these variables will not have strong effects empirically on farm, off-farm, and home hours.

Some important issues that may affect how husbands and wives allocate their time have been neglected. Different sources of income may be taxed differently. Useful tax information is, however, not available. Hours of work may be directly a source of utility or disutility. This we cannot easily test empirically. Current on-the-job experience can be expected to raise future labor productivity. An individual's age is highly correlated with the length of the expected payoff period for human capital investments (Becker 1964; Mincer) and incentives for nonhuman asset accumulation are closely tied to age (Ghez and Becker). Thus, husband's age controls for several age-related effects on a household's choices.

The Econometric Model

The econometric model for husband's and wife's off-farm work contains a maximum of four structural equations — two market labor demand functions and two off-farm labor supply functions. The model is recursive in the sense that each market labor-demand function contains only one endogenous variable, the wage, but it excludes off-farm hours; and the off-farm labor supply functions contain endogenous variables of off-farm hours and one or two off-farm wage rates. This four-equation system is modified to permit structural
changes—variables included and coefficients—that are expected in the off-farm labor supply functions when a husband and (or) wife do not participate in off-farm work. The structure of the market labor demand functions are, however, not expected to be affected by a spouse's decision on off-farm work. They have only one structure for each sex.

The econometric model is equations (17)-(20):

(17) \[ W_1 = X_1 \beta_1 + v_1, \text{ if } W_1 > W_1^R \]

\( (W_1 \text{ is unobservable if } W_1 < W_1^R) \)

(18) \[ W_2 = X_2 \beta_2 + v_2, \text{ if } W_2 > W_2^R \]

\( (W_2 \text{ is unobservable if } W_2 < W_2^R) \)

(19) \[ T_{11}^m = W_1 a_{111} + W_2 a_{121} + z_{11} + \mu_{11}, \text{ if } W_1 > W_1^R \text{ and } W_2 > W_2^R \]

\[ = W_1 a_{122} + z_{12} + \mu_{12}, \text{ if } W_1 > W_1^R \text{ and } W_2 < W_2^R \]

\[ = 0, \text{ if } W_1 < W_1^R \text{ and } W_2 > W_2^R \]

\( \text{or } W_1 < W_1^R \text{ and } W_2 < W_2^R \)

(20) \[ T_{22}^m = W_1 a_{211} + W_2 a_{221} + z_{21} + \mu_{21}, \text{ if } W_1 > W_1^R \text{ and } W_2 > W_2^R \]

\[ = W_2 a_{222} + z_{22} + \mu_{22}, \text{ if } W_1 < W_1^R \text{ and } W_2 > W_2^R \]

\[ = 0, \text{ if } W_1 > W_1^R \text{ and } W_2 < W_2^R \]

\( \text{or } W_1 > W_1^R \text{ and } W_2 < W_2^R \)

where

\( W_j \) = hourly market wage rate of the j-th spouse, (j = 1 for husbands, 2 for wives),

\( X_j \) = vector of labor market and human capital variables for the j-th spouse,
\( w_{ij}^R \) = the reservation wage rate for off-farm work of the j-th spouse, 
\( T_{ij} \) = hours of off-farm wage work supplied by the j-th spouse, 
\( Z \) = vector of non-wage household and farm control variables, 
\( \beta_{ij}, a_{jk} \) = structural coefficients, 
\( v_j \) = random disturbance term in j-th spouse's labor demand equation, 
\( \mu_{jk} \) = random disturbance term in the j-th spouse's labor supply equation and k-th structure.

The reservation wage (for off-farm work) of an individual is the marginal value to the household of his (her) time when he (she) allocates all of his (her) time endowment to farm labor and home time. Given equation (17)-(20), the equations for the reservation wage are:

\[
W_{1}^R = \left(1/a_{11}\right)\left[\beta_{1} a_{12} + Z\alpha_{1} + \mu_{1} + v_{2} a_{12}\right] \\
W_{2}^R = \left(1/a_{22}\right)\left[\beta_{1} a_{21} + Z\alpha_{2} + \mu_{2} + v_{1} a_{21}\right]
\]

Thus, the reservation wage for an individual in a 2-adult joint decision-making farm household is a function of the exogenous variables and random disturbance terms of his (her) spouse's market labor demand function and the non-wage exogenous control variables and random disturbance term of his (her) off-farm labor supply function.

The conditional nature of the econometric structure represented in equations (17)-(20) suggests that they are endogenously determined and that switching of structures is endogenous. Each structure has a particular probability of occurrence. For the market labor demand equations, the probabilities are:

\[
(21) \quad P_1 = P_r [W_1 > \bar{W}_1] = P_r [\xi_1 > \Omega_1] \\
(22) \quad P_2 = P_r [W_2 > \bar{W}_2] = P_r [\xi_2 > \Omega_2]
\]
and for the off-farm labor supply functions the probabilities are:

\[(23.1) \quad P_{12} \equiv P_r(C_1) \equiv P_r[W_1 > W_1^R, W_2 > W_2^R] = P_r[\xi_1 > \Omega_1, \xi_2 > \Omega_2],\]
\[(23.2) \quad P_{10} \equiv P_r(C_2) \equiv P_r[W_1 > W_1^R, W_2 < W_2^R] = P_r[\xi_1 > \Omega_1, \xi_2 < \Omega_2],\]
\[(23.3) \quad P_{02} \equiv P_r(C_3) \equiv P_r[W_1 < W_1^R, W_2 > W_2^R] = P_r[\xi_1 < \Omega_1, \xi_2 > \Omega_2],\]
\[(23.4) \quad P_{00} \equiv P_r(C_4) \equiv P_r[W_1 < W_1^R, W_2 < W_2^R] = P_r[\xi_1 < \Omega_1, \xi_2 < \Omega_2],\]

where \(C_j\) indexes decision combinations and where:

\[\xi_1 = v_1 + [u_1/a_{11}] + [a_{12}/a_{11}] v_2,\]
\[\xi_2 = v_2 + [u_2/a_{22}] + [a_{21}/a_{22}] v_1,\]
\[\Omega_1 = -X_1 B_1 - X_2 B_2 [a_{12}/a_{11}] - Z [a_1/a_{11}],\]
\[\Omega_2 = -X_2 B_2 - X_1 B_1 [a_{21}/a_{22}] - Z [a_2/a_{22}].\]

Because of the nonrandom nature of different econometric structures, the conditional mean values of the disturbance terms of the market labor demand and off-farm labor supply functions are unlikely to be zero. These nonzero means are the potential source of sample selection bias when equations (17)-(20) are fitted. This problem can be corrected by adding one or more variables, which are the conditional mean value of the disturbance term, to each structural equation (Maddala 1981, 1983; Fische, Trost, and Lurie; Heckman).

Estimation of the multiple-equation endogenous switching econometric model, modified for sample selectivity, is made easier by its recursive structure. The market labor demand functions for husbands and wives can be fitted by least squares to observations on husbands and wives, respectively, who participate in off-farm wage work. Then off-farm labor supply equations can be fitted (i) to subsamples of observations that are matched to the structures or (ii) to the whole sample. To go the second route, an unconditional off-farm labor supply function must be obtained by weighting each of the separate conditional off-farm labor supply functions by its
probability of occurrence:

\[ T^m_j = \sum_{\mathcal{X}} E(T^m_j | C_*) P(T^m_j | C_*) + \mu^*_j, \quad E\mu^*_j = 0, \quad j = 1, 2, \]

where \( E \) is the expectations operator, \( T^m_j \) is defined in equations (19) and (20), and \( P(T^m_j | C_*) \) is defined in equation (23). Because \( E(T^m_1 | C_3) = E(T^m_1 | C_4) = E(T^m_2 | C_2) = E(T^m_2 | C_4) = 0 \), the unconditional off-farm labor supply equations for the husband and wife are respectively:

\[
(24) \quad T^m_1 = E(T^m_1 | C_1) P(T^m_1 | C_1) + E(T^m_1 | C_2) P(T^m_1 | C_2) + \mu^*_1,
\]

\[
(25) \quad T^m_2 = E(T^m_2 | C_1) P(T^m_2 | C_2) + E(T^m_2 | C_3) P(T^m_2 | C_3) + \mu^*_2.
\]

Each of the two different methods for estimating the off-farm labor supply functions has advantages and disadvantages. With the first method, near multicollinearity will be less serious than for the second method, other things equal. With the first method, the number of observations matching any one structure can be small relative to the total sample size and relative to the number matching other structures. Furthermore, the observations, where off-farm hours are zero, are not used directly in fitting the off-farm labor supply functions. With the second procedure, all observations are employed to fit the off-farm labor supply functions. Each husband (wife) in the sample has a nonzero probability of being included in any one of the four decision combinations that determine the structure of his (her) off-farm labor supply function. The additional observations can be helpful in identifying the parameters of the off-farm labor supply functions (Maddala 1981).

The Data and Empirical Results

The model of off-farm labor supply is to be fitted to data for a random sample of Iowa farm households collected in 1977.
The Data

The data for the empirical analysis were obtained from a micro farm-household data set. The data set was created from information collected in a sample survey of Iowa farms and associated farm households. The population of farms surveyed was all farms having gross farm sales of $2,500 or more in 1976. Farms for interviewing were selected by area probability sampling. The farm operator was identified as the primary decision-maker for the farm business. The farm operator and spouse, when one was present, make up the primary household unit. The survey was designed and conducted by the Statistics Laboratory, Iowa State University. Interviewers collected extensive information about farm business and household characteristics from 933 households.

Husband-wife households of the survey provide the data for this study. These males and females have traditional divisions of labor or specializations. Husbands allocate most of their time to farm work and wives allocate most of their hours to home time. However, sixty-five percent of the wives reported some annual hours of farm work. Off-farm wage work was reported by 25 percent of the husbands and 28 percent of the wives.

The empirical definitions of the variables and summary statistics are reported in Table 1. Off-farm wage work is measured in annual hours. Age and age squared control for non-linear life cycle and work-experience effects in labor demand functions and off-farm labor supply equations. Two general schooling variables are considered. Additional formal schooling is expected to raise off-farm wage offers (Summer 1982) and to enhance the efficiency of farm (Huffman 1974) and household production. Being farm raised reflects early on-the-job farm training, which may affect farming activity choices, and
opportunities for obtaining land from relatives for farming. Asset income is measured by expected income from net worth in farmland and nonfarm assets. Children of different ages have been shown to differ in their home-time intensity (Gronau 1977; Leibowitz 1972), so we specify the number of children at home in three age groups: less than 6 years, 6-11 years, and 12-18 years.

Two location variables are included in the off-farm labor supply and demand equations. First, a potential commuting distance variable is defined as the distance in miles from the farm to the nearest city that has a population of 10,000 or more. This variable is entered in quadratic form in the off-farm labor supply equations to permit nonlinear marginal effects of distance. Second, a dummy variable for location in the eastern versus western half of the state is defined for the off-farm labor demand equation. With sufficient geographical immobility of firms and employers, greater density of urbanization and industrialization in eastern than western sections of the state may affect farm and off-farm wage rates. Also, some characteristics of the agricultural environment are different between the regions. Thus, the regional dummy represents both labor market and agricultural differences. A separate variable is added, however, to represent the length of the normal crop growing season, which increases from north to south. A longer growing season is expected to increase the productivity of farm labor. The growing season variable is measured by growing-degree days.

The Results

Off-farm work participation

Probit estimates of parameters for off-farm work participation equations of two-adult households are displayed in Table 2. Univariate decisions of husbands and of wives are explained in the two left columns of Table 2. Bivariate decisions are explained in the three right columns. All
equations are reduced-forms, containing regressors that are assumed to be exogenous when off-farm work decisions are made by households.

The equations provide estimated coefficients that are largely consistent with \textit{a priori} expectations. The results show that husband's age has a positive but diminishing marginal effect on the probability of the single decision that his wife works off-farm and on the joint decisions that both he and she work off-farm and that only his wife works off-farm. Increasing husband's age, other things equal, reduces the probability of the single decision that he works off-farm and the joint decision that only he works off-farm. These age effects, however, are not strong statistically.

General human capital in the form of education strongly affects off-farm work decisions. In contrast to Sumner's findings for Illinois farmers but in support of earlier results (Huffman 1980), a husband or wife who has completed more general schooling has a significantly higher probability of participating in off-farm work than individuals who have less schooling. The signs and significance of the estimated coefficients associated with general schooling are consistent with household decisions based on relative comparative advantage stemming from prior investment in human capital in the form of completion of formal training (Becker 1981). Additional husband's schooling also increases probability of the joint decision that both he and she work off-farm or that only the husband works off-farm. His additional schooling reduces the probability that only his wife works off-farm. Additional wife's schooling also increases the probability of the joint decisions that both he and she work off-farm and that only she works off-farm. Increases in her schooling reduce the probability of her husband's off-farm work and of the joint decision that only he works off-farm. These results are consistent with the hypothesis that investments in general schooling increase an individual's
off-farm wage by more than it increases the opportunity cost of their time in farm and (or) home activities.

Young children have a surprisingly negative effect on both husband's and wife's off-farm work probabilities. Increasing the number of children under age 6 causes a statistically significant decrease in the probability that either the husband or wife works off-farm and the joint decision that both he and she work off-farm. The effect of additional young children on the probability that only the husband or only the wife works off-farm is not statistically different from zero. Additional children age 6-12 years cause statistically significant reductions of probabilities that the wife works off-farm and only she works off-farm. Increases in the number of children ages 6-12 years increases the probabilities that the husband works off-farm and that only he works off-farm, however, the effects are not statistically significant. The presence of older children 12-18 years of age has no statistically significant effect on off-farm work probabilities.

Off-farm jobs are concentrated in cities. Thus, the expected commuting distance and cost of commuting increases for households located at greater distance from urban areas. Holding the off-farm wage constant, a longer commute, i.e., larger MCITY, reduces the net wage and has the expected negative and significant effect of reducing the probability that either one or both of the adults work off-farm. The negative effect of MCITY diminishes as MCITY increases. Off-farm jobs are more numerous and evenly dispersed in the eastern than in the western region of the state. Also agri-climate conditions differ. Unexpectedly a household being located in the western region of the state tends to increase the probability of either or both adults working off-farm. As expected a longer agricultural growing season, i.e., larger GDD, reduces the probability that the husband works off-farm.
Being farm raised, as expected, significantly reduces the probability of any off-farm work by the husband, and also reduces the probability that his wife works off-farm. Larger asset income reduces the probability that either or both of the adults works off-farm. The effect of additional asset income is positive on the probabilities of the joint decision that only husband or wife works off-farm, however, the effect is not statistically significant.

**Off-farm labor demand functions**

The off-farm labor demand functions (see equations 21-23) for husbands and wives are fitted to observations contained in the three subsample data sets. Each of the demand equations contains two sample selection variables.\(^{13}\)

The estimated coefficients of the labor demand functions, reported in Table 3, are consistent with expectations. The dependent variable is the natural logarithm of the hourly wage. An individual's schooling has a positive effect on his (her) wage rate. A one year increase in general schooling for the husband, all else equal, increases his hourly wage 5.6 percent. For the wife, a one year increase in her schooling increases her hourly wage 4.5 percent. An individual's experience (\(\text{EXP}_j\)), measured as \(\text{Age}_j - \text{Ed}_j - 6\), has a positive but diminishing marginal effect on \(\ln W_j\), \(j = 1, 2\). As expected, the regional dummy variable indicates lower hourly wages for the western region and indicates approximately 30 percent lower hourly rates for women. The estimates of coefficients for the sample selection variables, \(G\)'s, suggest the existence of statistically significant sample selection effects on labor demand.
Off-farm labor supply functions

Although both conditional and unconditional off-farm labor supply equations are fitted, results from the unconditional equations are evaluated most extensively. When the conditional off-farm labor supply equations for husbands (wives), adjusted for bivariate sample selectivity, were fitted to matched subsamples, the t-ratios on all the estimated coefficients were small, but R²'s were respectable in size for microdata, e.g., .10 to .31. These poor results seem to be due to generally small subsample sizes, e.g., 70 households where the husband and wife both worked off-farm and only modestly larger observation numbers for the other subsamples, and near-multicollinearity.¹⁴

See Appendix 2.

To overcome these problems, we made two changes. First, we changed to the unconditional off-farm labor supply equations, equations (24) and (25), where all observations for husbands and wives, respectively, are pooled together into a Tobit-type (Tobin) equation. Second, we changed from the least squares to the ridge-regression estimator.¹⁵ The ridge estimator frequently has relatively good properties when near-multicollinearity is a problem (Vinod 1978; Lin and Kmenta 1982).

Several variants of the ridge-regression estimator exist (Amemiya 1985, Ch. 2). Although the Bayesian version (Amemiya 1985, p. 61) provides an appealing method for estimating the ridge scalar (γ), this procedure failed because the estimate of γ was larger than one. The procedure we employed next is suggested by Koerl, Kennard, and Baldwin (1975). Their procedure resulted in estimates of γ of 0.31 and 0.55 for the off-farm labor supply equations of husbands and wives, respectively. Stability of the ridge estimators was checked and estimates of γ were shown to change by less than one-tenth of one percent for each .01 increment to γ.
Estimates of Tobit-type incremental responses of expected annual off-farm hours to changes in the exogenous variables for the Iowa farm households are presented in Table 4. For adults of a given sex, a joint test was performed on the coefficients to see if nonwage variables had similar coefficients in the two household structures. This test for husbands in decision groups 1 and 2, and for wives in groups 1 and 3 was rejected at the 1 percent significance level. The incremental expected response elasticities for the population of husbands (wives) are weighted averages of responses for the different response structures. For example, the own-wage elasticity of husbands' expected off-farm work is \( a_{111}^P p_{12} + a_{122}^P p_{10} \), and the absolute change in husbands' expected off-farm hours if

\[
( a_{111}^P p_{12} + a_{122}^P p_{10} ) T_1 / W_1. 
\]

When variables appear in equations for evaluating incremental effects of exogenous variables, they are set at sample mean values. The estimates of expected incremental responses of husband's and wife's annual off-farm hours to the exogenous variables may seem small. (See Table 5.) This is because the response coefficients are weighted by the probability that any off-farm work occurs, and these probabilities are relatively small.

Age has a positive but diminishing marginal effect on his off-farm hours in households where both the husband and wife work off-farm. In these households, the effect of husband's age on his wife's off-farm hours is positive and slightly increasing. In households where only the husband works off-farm, his age has a positive and slightly increasing marginal effect on his off-farm hours. In households where only the wife works off-farm, an increase in his age has a positive but diminishing marginal effect on her hours of off-farm work. The net result is that an increase in husband's age
increases the expected hours of off-farm work of husbands as a group and wives as a group. The elasticities of expected response are 0.1 and 0.75, respectively.

Although income elasticities of off-farm work are a priori ambiguous in sign, the positive income elasticity of husbands' off-farm hours indicates that their leisure time is an inferior good. For wives, leisure time is a normal good. For the population, the asset income elasticity of expected off-farm hours is small, being -0.01 for husbands and 0.01 for wives. Although these income elasticities are small and have small t-ratios, their signs are consistent with studies of male and female labor supply for wage earning nonfarm household members (Keeley).

The own-wage elasticity of expected off-farm work hours for the population of husbands and wives residing on Iowa farms is positive. This occurs because the estimated wage elasticities of off-farm hours for all household types are positive. The own elasticity is 0.03 for husbands and 0.09 for wives. A one dollar per hour increase in the off-farm wage rate increases husbands' annual off-farm work by an average of 2.3 hours per year and wives by an average of 9 hours per year. Cross-wage elasticities of expected off-farm labor supply are also positive, and their size compares favorably with the own-wage elasticities.

Other things equal, an increase in either adult's education increases expected off-farm work by husbands and wives. This result is consistent with a number of different farm and household production and income effects. The own-elasticity effects are the same for husbands and wives (0.22), but the expected incremental change of hours is larger for husbands than for wives (7.5 hours per year versus 2.6). The own effects of general schooling on expected off-farm hours and the previously noted positive impact of schooling
on off-farm work participation support the results reported by Huffman.

An increase in the number of children who are less than 6 years of age per household increases husbands' expected off-farm work by an average of 39 hours per year and reduces average off-farm hours of wives by 14 per year. For husbands, the positive effect of additional young children on expected off-farm hours is a result of the positive effect (elasticity of 1.17) in households where only the husband works off-farm dominating the negative effect (elasticity of -0.52) in households where both adults work off-farm. For wives, the estimated coefficients on $K_1$ are negative in both household structures, and they are not significantly different when both the husband and wife work off-farm or when only the wife works off-farm. The relatively larger effect of young children on husbands' off-farm hours is contrary to the effects of additional young children on hours of work of nonfarm married males. For these households, a larger number of children ages 6-11 or 12-18 increases both adult's expected off-farm work hours, and the expected increase is larger for husbands than for wives.

Although a larger MCITY reduces the probability that husbands and wives participate in off-farm work, a larger MCITY increases expected off-farm hours of husbands. The positive effect on husband's hours for households where only the husband works off-farm outweighs the negative effect for households where both adults work off-farm. For wives, the negative effect of MCITY for households where only the wife works off-farm is dominate. For husbands, these results are surprising because leisure is an inferior good. The elasticity estimates are 0.15 for husbands and -0.03 for wives.

A longer growing season (larger GDD) increases expected off-farm work hours of husbands and wives. The direction of the responses is the same in
all household structures. The estimated elasticities are 0.43 and 0.26 for husbands and wives, respectively.

Conclusions

This study has considered joint decisions of farm households for husband's and wife's labor supplied to the external labor market. Binding non-negativity constraints were frequently encountered for these decisions. To accommodate these complexities, a multiple-equation econometric model was developed where endogenous switching of econometric structures of the off-farm labor supply equations occurred whenever a binding non-negativity constraint occurred.

Multiple binding non-negativity constraints are reasonably common phenomena in empirical research. They may arise whenever a number of joint decisions are being made by economic agents. In agriculture, farmers made decisions on multiple outputs, and in a sample of farms, a significant share of them will be against non-negativity constraints for two or more outputs. In nonfarm households, multiple binding non-negativity constraints can be expected to occur when husband's and wife's labor supply decisions are considered jointly with demand decisions for commodities. These complexities are, however, seldom explicitly incorporated into econometric models.

Our experience may be useful to others. We encountered several problems when we implemented our econometric model that was adapted for two binding non-negativity constraints. For the conditional off-farm supply structure, these problems included (i) small subsample sizes for each endogenous structure and (ii) small t-ratios for estimated coefficients. The alternative specification of unconditional off-farm labor supply equations permitted us to
use all of the observations in estimation, but it suffered from near-multicollinearity. These are all problems that other researchers might expect to encounter when they attempt to model a larger number of joint decisions of economic agents and to fit econometric models incorporating the effects of multiple binding non-negativity constraints.
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Footnotes

* The authors are Professor of Economics, Iowa State University, and Assistant Professor of Agricultural Economics, Louisiana State University. Helpful comments on earlier drafts were obtained from Robert Emerson, Randy Olsen, Ken Wolpin, Peter Orazem, and John Strauss. Financial support from the Iowa and Louisiana Agricultural Experiment Stations is acknowledged.

1 Farm households are predominantly of the husband-wife type. In our survey, they accounted for 92 percent of all farm households.

2 In a two-period model the role of saving and investing are more integral to optimizing behavior.

3 This specification neglects the time cost of commuting. M is treated as fixed.

4 The assumption of wage independency from current hours worked is common in labor supply studies. For some exceptions see Hausman or Rosen.

5 For the data set employed in this study, less than 10 percent of total farm hours are (from outside the household).

6 In this model economic outcomes are certain. The introduction of risk-neutral attitude toward uncertainty into the model will not change the predictions of the model.

7 The equations for the means of the disturbance terms are derived in Appendix A.

8 The response rate was a relatively high 88 percent and the Statistical Laboratory frequently called back households to obtain missing information and to verify information. The survey of Illinois farmers, which provided the data for Sumner's off-farm labor supply study, had only a 40 percent return
rate. Because of nonrandom selection, nonresponse is a potential source of biased regression results (Heckman 1979).

There are 771 husband-wife households used in this study. Of the 933 total households, eighty-nine were excluded because they were not a husband-wife household type and the remainder were excluded because of missing essential data.

We include husband's but not wife's age in labor supply equations. This reduces problems with multicollinearity and interpretation because husband's and wife's age will be highly correlated.

Acres operated and farm capital in machinery and livestock are excluded from the set of regressors because they are household decision variables which are determined jointly with time allocation.

These are approximate bivariate probabilities. The procedure employed here takes account of the correlation of husband's and wife's off-farm work decisions and is a significant improvement over the univariate probabilities which assumes that participation decisions of spouses are independent.

Ordinary least squares estimates of these wage equations when sample selection terms are included yields statistically consistent estimates (Maddala 1983; Lee, Maddala, Trost).

Also, Nelson (1984) has shown that multiple step estimation procedures frequently have relatively low efficiency.

For the model, $\mathbf{y} = \mathbf{X}\beta + \nu$, the class of estimators defined by $\hat{\beta}(\gamma) = (\mathbf{X}'\mathbf{X} + \gamma I)^{-1} \mathbf{X}'\mathbf{y}$ are called ridge estimators. The ridge scalar is $\gamma$.

Vinod (1978) concludes that decisions from tests of hypotheses that employ the ridge regressor may be affected by the bias of the estimator. The stability of the estimator, however, proves quite useful in estimating marginal effects and elasticities.
Table 1. A Summary of Empirical Definitions and Means of Variables (771 observations)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitions</th>
<th>Symbol</th>
<th>Mean</th>
<th>(Std. Dev.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Endogenous</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Univariate off-farm work status for individual j, j = 1 (husband), 2 (wife) -- A 1,0 dummy variable taking a value of 1 if the individual reports positive annual hours of off-farm work, and 0 otherwise.</td>
<td>$P_1$</td>
<td>0.25</td>
<td>(0.43)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$P_2$</td>
<td>0.28</td>
<td>(0.45)</td>
</tr>
<tr>
<td>Bivariate off-farm work status</td>
<td>a) A 1,0 dummy variable taking a value of 1 if both the husband and wife report off-farm wage work, and 0 otherwise.</td>
<td>$P_{12}$</td>
<td>0.099</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) A 1,0 dummy variable taking a value of 1 if the husband reports off-farm wage work but wife does not, and 0 otherwise.</td>
<td>$P_{10}$</td>
<td>0.119</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) A 1,0 dummy variable taking a value of 1 if the wife reports positive off-farm wage work but husband does not, and 0 otherwise.</td>
<td>$P_{02}$</td>
<td>0.145</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d) A 1,0 dummy variable taking a value of 1 if neither husband nor wife report any off-farm wage work.</td>
<td>$P_{00}$</td>
<td>0.595</td>
<td></td>
</tr>
<tr>
<td>Off-farm labor -- Annual hours of off-farm work for a wage or salary. This excludes work at a nonfarm self-employed business and custom or contract work on another farm.</td>
<td>$T_1^m$</td>
<td>305.3</td>
<td>(694.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and custom or contract work on another farm.</td>
<td>$T_2^m$</td>
<td>292.8</td>
<td>(617.1)</td>
</tr>
<tr>
<td>Off-farm wage rate -- Annual earnings from off-farm wage and salary income divided by annual hours of off-farm wage work for j-th individual ($/hr).</td>
<td>$W_1$</td>
<td>3.97</td>
<td>(2.9)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$W_2$</td>
<td>4.35</td>
<td>(14.5)</td>
</tr>
<tr>
<td><strong>B. Exogenous</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Husband's age in years. This variable is also squared.</td>
<td>$AG_1$</td>
<td>47.9</td>
<td>(12.8)</td>
<td></td>
</tr>
<tr>
<td>Education -- Years of formal schooling completed. This excludes vocational training obtained in a business or trade school.</td>
<td>$ED_1$</td>
<td>11.3</td>
<td>(2.3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$ED_2$</td>
<td>12.1</td>
<td>(1.9)</td>
</tr>
</tbody>
</table>
Table 1. Continued.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitions</th>
<th>Symbol</th>
<th>Mean</th>
<th>(Std. Dev.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm raised - A 1,0 dummy variable, taking a value of 1 if husband was raised on a farm, and 0 otherwise.</td>
<td>D(FA(RAISED)(_1))</td>
<td>0.93</td>
<td>(0.25)</td>
<td></td>
</tr>
<tr>
<td>Asset income - An estimate of annual household interest income from the household's net worth in farmland, stocks, bonds and nonfarm businesses.</td>
<td>V(_{OF})</td>
<td>11,613.4</td>
<td>(29,792.)</td>
<td></td>
</tr>
<tr>
<td>Children - Number of children in the household by age group, (1) &lt; 6 years, (2) 6-11 years, and (3) 12-18 years.</td>
<td>K(_1), K(_2), K(_3)</td>
<td>0.26</td>
<td>(0.59)</td>
<td></td>
</tr>
<tr>
<td>Distance to a city - The number of miles from the farmstead to the nearest city that has a population of 10,000 or more. This variable is also squared.</td>
<td>MCITY</td>
<td>27.5</td>
<td>(14.5)</td>
<td></td>
</tr>
<tr>
<td>Geographical region - A 1,0 dummy variable, taking a value of 1 if a household is located in the western half of the state, and 0 otherwise.</td>
<td>D(WEST)</td>
<td>0.51</td>
<td>(0.50)</td>
<td></td>
</tr>
<tr>
<td>Growing degree days - A measure of the normal crop growing season, measured as average growing-degree-days accumulated between spring and fall dates of &lt; 10 percent frost probability.</td>
<td>GDD</td>
<td>2954.4</td>
<td>(149.2)</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Probit Estimates of Univariate and Bivariate Probabilities of Off-Farm Work of Iowa Farmers and Their Spouses, 1976. (Absolute values of asymptotic t-ratios in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P12</th>
<th>P10</th>
<th>P02</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG1</td>
<td>-0.00177</td>
<td>0.0392</td>
<td>0.0598</td>
<td>-0.0186</td>
<td>0.0402</td>
</tr>
<tr>
<td></td>
<td>(0.44)</td>
<td>(1.02)</td>
<td>(1.01)</td>
<td>(0.42)</td>
<td>(0.98)</td>
</tr>
<tr>
<td>AG2</td>
<td>-0.00019</td>
<td>-0.0007</td>
<td>-0.0009</td>
<td>0.0001</td>
<td>-0.0006</td>
</tr>
<tr>
<td></td>
<td>(0.44)</td>
<td>(1.61)</td>
<td>(1.39)</td>
<td>(0.15)</td>
<td>(1.38)</td>
</tr>
<tr>
<td>ED1</td>
<td>0.0879</td>
<td>0.0429</td>
<td>0.0789</td>
<td>0.0507</td>
<td>-0.0023</td>
</tr>
<tr>
<td></td>
<td>(2.98)</td>
<td>(1.51)</td>
<td>(1.92)</td>
<td>(1.51)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>ED2</td>
<td>-0.0793</td>
<td>0.0718</td>
<td>0.0001</td>
<td>-0.1053</td>
<td>0.0918</td>
</tr>
<tr>
<td></td>
<td>(2.39)</td>
<td>(2.24)</td>
<td>(0.00)</td>
<td>(2.76)</td>
<td>(2.66)</td>
</tr>
<tr>
<td>D(FRAISED1)</td>
<td>-0.5041</td>
<td>-0.2967</td>
<td>-0.5538</td>
<td>-0.2089</td>
<td>0.1473</td>
</tr>
<tr>
<td></td>
<td>(2.47)</td>
<td>(1.45)</td>
<td>(2.29)</td>
<td>(0.90)</td>
<td>(0.59)</td>
</tr>
<tr>
<td>K1</td>
<td>-0.2382</td>
<td>-0.3197</td>
<td>-0.3041</td>
<td>-0.0788</td>
<td>-0.2091</td>
</tr>
<tr>
<td></td>
<td>(2.19)</td>
<td>(2.92)</td>
<td>(2.09)</td>
<td>(0.65)</td>
<td>(1.76)</td>
</tr>
<tr>
<td>K2</td>
<td>0.0276</td>
<td>-0.1706</td>
<td>-0.1107</td>
<td>0.0675</td>
<td>-0.1681</td>
</tr>
<tr>
<td></td>
<td>(0.41)</td>
<td>(2.41)</td>
<td>(1.17)</td>
<td>(0.91)</td>
<td>(2.11)</td>
</tr>
<tr>
<td>K3</td>
<td>0.0528</td>
<td>-0.0379</td>
<td>0.0633</td>
<td>0.0266</td>
<td>-0.0942</td>
</tr>
<tr>
<td></td>
<td>(0.99)</td>
<td>(0.72)</td>
<td>(0.91)</td>
<td>(0.44)</td>
<td>(1.55)</td>
</tr>
<tr>
<td>D(W)</td>
<td>0.1761</td>
<td>0.1354</td>
<td>0.2022</td>
<td>0.1088</td>
<td>0.0510</td>
</tr>
<tr>
<td></td>
<td>(1.57)</td>
<td>(1.25)</td>
<td>(1.33)</td>
<td>(0.87)</td>
<td>(0.43)</td>
</tr>
<tr>
<td>ln VOF</td>
<td>-0.0107</td>
<td>-0.0082</td>
<td>-0.0393</td>
<td>0.0128</td>
<td>0.0127</td>
</tr>
<tr>
<td></td>
<td>(0.99)</td>
<td>(0.77)</td>
<td>(2.71)</td>
<td>(1.04)</td>
<td>(1.08)</td>
</tr>
<tr>
<td>CITY</td>
<td>-0.0501</td>
<td>-0.0314</td>
<td>-0.0542</td>
<td>-0.0271</td>
<td>-0.0024</td>
</tr>
<tr>
<td></td>
<td>(3.78)</td>
<td>(2.41)</td>
<td>(3.28)</td>
<td>(1.84)</td>
<td>(0.16)</td>
</tr>
<tr>
<td>CITY2</td>
<td>0.0008</td>
<td>-0.0004</td>
<td>0.0008</td>
<td>0.0004</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>(3.66)</td>
<td>(2.20)</td>
<td>(3.05)</td>
<td>(1.86)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>GDD</td>
<td>-0.0008</td>
<td>0.0001</td>
<td>0.0001</td>
<td>-0.0009</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>(1.91)</td>
<td>(0.15)</td>
<td>(0.09)</td>
<td>(2.18)</td>
<td>(0.30)</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>3.2459</td>
<td>1.5559</td>
<td>-1.6227</td>
<td>3.3106</td>
<td>3.0119</td>
</tr>
<tr>
<td></td>
<td>(2.12)</td>
<td>(1.04)</td>
<td>(0.75)</td>
<td>(1.95)</td>
<td>(1.86)</td>
</tr>
</tbody>
</table>

χ² = 64.52  58.56  59.81  25.41  26.38

n = 771
Table 3. Off-Farm Labor Demand Functions: Iowa Farm Households, 1976
(Absolute values of t-ratios in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Husband</th>
<th>Wife</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.7142 (1.81)</td>
<td>0.2193 (0.29)</td>
</tr>
<tr>
<td>EDUC&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0.0558 (2.45)</td>
<td>EDUC&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>EXP&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0.0343 (2.07)</td>
<td>EXP&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>EXP&lt;sub&gt;2&lt;/sub&gt;</td>
<td>-0.0007 (2.15)</td>
<td>EXP&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>D(W)</td>
<td>-0.0964 (1.11)</td>
<td>D(W)</td>
</tr>
<tr>
<td>G&lt;sub&gt;11&lt;/sub&gt;</td>
<td>-0.0053 (2.05)</td>
<td>G&lt;sub&gt;21&lt;/sub&gt;</td>
</tr>
<tr>
<td>G&lt;sub&gt;12&lt;/sub&gt;</td>
<td>-0.0013 (2.07)</td>
<td>G&lt;sub&gt;22&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

R<sup>2</sup> = 0.19
n-k = 170

<sup>a/</sup>See Appendix for definition of Gs.
Table 4. Tobit-Type Ridge-Regression Estimates of Off-Farm Labor Supply Functions for Iowa Farmers and Their Wives, 1976. (Absolute values of approximate t-ratios in parentheses)

<table>
<thead>
<tr>
<th>Variables/coefficients</th>
<th>ln (off-farm hours)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Husbands</td>
<td>Wives</td>
</tr>
<tr>
<td></td>
<td>$P_{12}$</td>
<td>$P_{10}$</td>
</tr>
<tr>
<td>$\ln W_1$</td>
<td>0.1903</td>
<td>0.0687</td>
</tr>
<tr>
<td></td>
<td>(3.76)</td>
<td>(1.01)</td>
</tr>
<tr>
<td>$\ln W_2$</td>
<td>0.4858</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.51)</td>
<td></td>
</tr>
<tr>
<td>$AG_1$</td>
<td>0.0224</td>
<td>0.0128</td>
</tr>
<tr>
<td></td>
<td>(2.37)</td>
<td>(1.73)</td>
</tr>
<tr>
<td>$AG_1^2$</td>
<td>-0.0002</td>
<td>0.0002</td>
</tr>
<tr>
<td></td>
<td>(0.51)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>$ED_1$</td>
<td>0.1132</td>
<td>0.0586</td>
</tr>
<tr>
<td></td>
<td>(4.21)</td>
<td>(1.97)</td>
</tr>
<tr>
<td>$ED_2$</td>
<td>0.1047</td>
<td>0.0563</td>
</tr>
<tr>
<td></td>
<td>(3.73)</td>
<td>(1.58)</td>
</tr>
<tr>
<td>$D(FRAISED_1)$</td>
<td>0.1669</td>
<td>0.6185</td>
</tr>
<tr>
<td></td>
<td>(0.24)</td>
<td>(0.99)</td>
</tr>
<tr>
<td>$K_1$</td>
<td>-0.5195</td>
<td>1.1680</td>
</tr>
<tr>
<td></td>
<td>(0.52)</td>
<td>(1.52)</td>
</tr>
<tr>
<td>$K_2$</td>
<td>0.2011</td>
<td>0.2281</td>
</tr>
<tr>
<td></td>
<td>(0.38)</td>
<td>(0.62)</td>
</tr>
<tr>
<td>$K_3$</td>
<td>0.6676</td>
<td>0.0889</td>
</tr>
<tr>
<td></td>
<td>(1.68)</td>
<td>(0.29)</td>
</tr>
<tr>
<td>CITY</td>
<td>-0.0106</td>
<td>0.0371</td>
</tr>
<tr>
<td></td>
<td>(0.99)</td>
<td>(2.27)</td>
</tr>
<tr>
<td>CITY$^2$</td>
<td>-0.0003</td>
<td>0.0008</td>
</tr>
<tr>
<td></td>
<td>(1.62)</td>
<td>(2.11)</td>
</tr>
<tr>
<td>$ln V_{OF}$</td>
<td>0.0581</td>
<td>0.0141</td>
</tr>
<tr>
<td></td>
<td>(0.77)</td>
<td>(0.28)</td>
</tr>
<tr>
<td>GDD</td>
<td>0.0006</td>
<td>0.0006</td>
</tr>
<tr>
<td></td>
<td>(5.37)</td>
<td>(5.29)</td>
</tr>
</tbody>
</table>
Table 4. Continued

<table>
<thead>
<tr>
<th>Term</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{G}<em>{31}$ or $\hat{G}</em>{41}$</td>
<td>0.0002</td>
<td>(0.38)</td>
<td></td>
</tr>
<tr>
<td>$\hat{G}<em>{32}$ or $\hat{G}</em>{42}$</td>
<td>-0.0001</td>
<td>(0.38)</td>
<td></td>
</tr>
<tr>
<td>$\hat{G}<em>{33}$ or $\hat{G}</em>{43}$</td>
<td>-0.0002</td>
<td>(0.32)</td>
<td></td>
</tr>
<tr>
<td>$\hat{G}<em>{34}$ or $\hat{G}</em>{44}$</td>
<td>-0.0001</td>
<td>(0.46)</td>
<td></td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>0.0808</td>
<td>(0.35)</td>
<td>1.1231</td>
</tr>
</tbody>
</table>

R²  | 0.41  | 0.12  |
| n - k | 740   | 740   |

The variables in each regression equation were multiplied by the probability that appears at the top of the column.

See Appendix for definition of $G$s.
Table 5. Estimates of Expected Incremental Response of Off-Farm Hours to Changes in Exogenous Variables: Iowa Farm Households, 1976. (Evaluated at sample means)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Husband</th>
<th></th>
<th></th>
<th>Wife</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Absolute effect (hours/yr)</td>
<td>Relative effect (elasticity)</td>
<td></td>
<td>Absolute effect (hours/yr)</td>
<td>Relative effect (elasticity)</td>
<td></td>
</tr>
<tr>
<td>$W_1$</td>
<td>2.27</td>
<td>0.03</td>
<td></td>
<td>0.86</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>$W_2$</td>
<td>6.38</td>
<td>0.07</td>
<td></td>
<td>8.94</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>$V_{OF}$</td>
<td>0.0001</td>
<td>0.01</td>
<td></td>
<td>-0.012</td>
<td>-0.01</td>
<td></td>
</tr>
<tr>
<td>$ED_1$</td>
<td>7.54</td>
<td>0.22</td>
<td></td>
<td>1.4</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>$ED_2$</td>
<td>7.07</td>
<td>0.21</td>
<td></td>
<td>2.56</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>$K_1$</td>
<td>38.6</td>
<td>0.02</td>
<td></td>
<td>-14.1</td>
<td>-0.03</td>
<td></td>
</tr>
<tr>
<td>$K_2$</td>
<td>19.7</td>
<td>0.03</td>
<td></td>
<td>6.44</td>
<td>0.02</td>
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<tr>
<td>$K_3$</td>
<td>31.4</td>
<td>0.06</td>
<td></td>
<td>0.59</td>
<td>0.01</td>
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<tr>
<td>$AG_1$</td>
<td>0.319</td>
<td>0.10</td>
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<td>2.75</td>
<td>0.75</td>
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<tr>
<td>CITY</td>
<td>2.25</td>
<td>0.15</td>
<td></td>
<td>-0.174</td>
<td>-0.03</td>
<td></td>
</tr>
<tr>
<td>GDD</td>
<td>0.058</td>
<td>0.43</td>
<td></td>
<td>0.013</td>
<td>0.26</td>
<td></td>
</tr>
</tbody>
</table>
Appendix A

Recall that $\xi_1 = v_3 + \frac{\mu_1}{a_{11}} + \frac{a_{12}}{a_{11}} v_2$ and $\xi_2 = v_2 + \frac{\mu_2}{a_{22}} + \frac{a_{21}}{a_{22}} v_1$

where $v_1, v_2, \mu_1,$ and $\mu_2$ are assumed normally distributed random variables, then

$E[v_j/\xi_1, \xi_2] = \rho_{1j} \cdot 2 \cdot E\xi_1 + \rho_{2j} \cdot 1 \cdot E\xi_2$ where $E =$ the expectations operator and $\rho_{ij,k}$ are the coefficients from the regression $v_j = \rho_{1j} \cdot 2 \cdot \xi_1 + \rho_{2j} \cdot 1 \cdot \xi_2 + \psi_j$, $j = 1, 2, E\psi_j = 0$. Furthermore, assume that the two sets of random disturbance terms $v_2, \xi_1$ and $\xi_2$ and $v_4, \xi_1$, and $\xi_2$ have trivariate normal distributions.

Then (Johnson and Kotz) the means of the off-farm hours equations for the selected subsamples are:

$E(\mu_{11}) = E[\mu_1/\xi_1 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{11} \cdot \mu_1 \cdot \xi_1 + \rho_{12} \cdot \mu_1 \cdot \xi_2/\xi_1 > \Omega_1, \xi_2 > \Omega_2]$

$= \rho_{11} \cdot \mu_1 \cdot \xi_2 \cdot \frac{1}{P_{12}} \left[ \sigma_{\xi_1}^2 \frac{f_{\xi_2}}{\xi_2} (1-F_{\xi_2}) + \sigma_{\xi_2}^2 \frac{f_{\xi_1}}{\xi_1} (1-F_{\xi_1}) \right]$

$+ \rho_{12} \cdot \mu_1 \cdot \xi_1 \cdot \frac{1}{P_{12}} \left[ \sigma_{\xi_2}^2 \frac{f_{\xi_2}}{\xi_2} (1-F_{\xi_2}) + \sigma_{\xi_2}^2 \frac{f_{\xi_1}}{\xi_1} (1-F_{\xi_1}) \right] = \Phi_1 \cdot 12 \cdot G_1 \cdot 3 \cdot \Phi_2 \cdot 12 \cdot G_2.$

$E(\mu_{12}) = E[\mu_1/\xi_1 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{11} \cdot \mu_1 \cdot \xi_1 + \rho_{12} \cdot \mu_1 \cdot \xi_2/\xi_1 > \Omega_1, \xi_2 > \Omega_2]$

$= \rho_{11} \cdot \mu_1 \cdot \xi_2 \cdot \frac{1}{P_{12}} \left[ \sigma_{\xi_1}^2 \frac{f_{\xi_2}}{\xi_2} (1-F_{\xi_2}) + \sigma_{\xi_2}^2 \frac{f_{\xi_1}}{\xi_1} (1-F_{\xi_1}) \right]$

$+ \rho_{12} \cdot \mu_1 \cdot \xi_1 \cdot \frac{1}{P_{12}} \left[ \sigma_{\xi_2}^2 \frac{f_{\xi_2}}{\xi_2} (1-F_{\xi_2}) + \sigma_{\xi_2}^2 \frac{f_{\xi_1}}{\xi_1} (1-F_{\xi_1}) \right] = \Phi_1 \cdot 12 \cdot G_3 \cdot 3 \cdot \Phi_2 \cdot 2 \cdot G_4.$

$E(\mu_{21}) = E[\mu_2/\xi_1 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{11} \cdot \mu_2 \cdot \xi_1 + \rho_{12} \cdot \mu_2 \cdot \xi_1/\xi_1 > \Omega_1, \xi_2 > \Omega_2]$

$= \rho_{11} \cdot \mu_2 \cdot \xi_2 \cdot \frac{1}{P_{12}} \left[ \sigma_{\xi_1}^2 \frac{f_{\xi_2}}{\xi_2} (1-F_{\xi_2}) + \sigma_{\xi_2}^2 \frac{f_{\xi_1}}{\xi_1} (1-F_{\xi_1}) \right]$

$+ \rho_{12} \cdot \mu_2 \cdot \xi_1 \cdot \frac{1}{P_{12}} \left[ \sigma_{\xi_2}^2 \frac{f_{\xi_2}}{\xi_2} (1-F_{\xi_2}) + \sigma_{\xi_2}^2 \frac{f_{\xi_1}}{\xi_1} (1-F_{\xi_1}) \right] = \Phi_1 \cdot 12 \cdot G_4 \cdot 3 \cdot \Phi_2 \cdot 2 \cdot G_5.$

$E(\mu_{23}) = E[\mu_2/\xi_1 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{11} \cdot \mu_2 \cdot \xi_1 + \rho_{12} \cdot \mu_2 \cdot \xi_1/\xi_1 > \Omega_1, \xi_2 > \Omega_2]$

$= \rho_{11} \cdot \mu_2 \cdot \xi_2 \cdot \frac{1}{P_{12}} \left[ \sigma_{\xi_1}^2 \frac{f_{\xi_2}}{\xi_2} (1-F_{\xi_2}) + \sigma_{\xi_2}^2 \frac{f_{\xi_1}}{\xi_1} (1-F_{\xi_1}) \right]$

$+ \rho_{12} \cdot \mu_2 \cdot \xi_1 \cdot \frac{1}{P_{12}} \left[ \sigma_{\xi_2}^2 \frac{f_{\xi_2}}{\xi_2} (1-F_{\xi_2}) + \sigma_{\xi_2}^2 \frac{f_{\xi_1}}{\xi_1} (1-F_{\xi_1}) \right] = \Phi_1 \cdot 12 \cdot G_5 \cdot 3 \cdot \Phi_2 \cdot 2 \cdot G_6.$
\[
\begin{align*}
\rho_{\xi_1^* \xi_2^*} & = \frac{1}{\rho_{\xi_1^* \xi_2^*}} \left[ \frac{\sigma^2_{\xi_1^* \xi_2^*} (1-F_-) + \sigma_{\xi_1^* \xi_2^*} (1-F_+)}{\sigma_{\xi_1^* \xi_2^*}^2} \Omega_1 \right] \\
+ \rho_{\xi_2^* \xi_1^*} & = \frac{1}{\rho_{\xi_2^* \xi_1^*}} \left[ \frac{\sigma^2_{\xi_2^* \xi_1^*} (1-F_-) - \sigma_{\xi_2^* \xi_1^*} (1-F_+)}{\sigma_{\xi_2^* \xi_1^*}^2} \Omega_2 \right]
\end{align*}
\]

where \( F_1 = F_{\xi_1^*} \Omega_1 \) and \( F_2 = F_{\xi_2^*} \Omega_2 \).

\[
E(v_{11}) = E[v_{11} / \xi_1 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{\xi_1^* \xi_2^*} v_{11} \xi_1 + \rho_{\xi_2^* \xi_1^*} v_{11} \xi_2 / \xi_1 > \Omega_1, \xi_2 > \Omega_2]
\]

\[
E(v_{12}) = E[v_{12} / \xi_1 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{\xi_1^* \xi_2^*} v_{12} \xi_1 + \rho_{\xi_2^* \xi_1^*} v_{12} \xi_1 / \xi_1 > \Omega_1, \xi_2 > \Omega_2]
\]

\[
E(v_{21}) = E[v_{21} / \xi_1 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{\xi_1^* \xi_2^*} v_{21} \xi_2 + \rho_{\xi_2^* \xi_1^*} v_{21} \xi_2 / \xi_1 > \Omega_1, \xi_2 > \Omega_2]
\]

\[
E(v_{22}) = E[v_{22} / \xi_1 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{\xi_1^* \xi_2^*} v_{22} \xi_2 + \rho_{\xi_2^* \xi_1^*} v_{22} \xi_2 / \xi_1 > \Omega_1, \xi_2 > \Omega_2]
\]

The wage equations for husbands (wives) are pooled over the two different household types where they work for a wage. The means of the disturbance terms in the wage equation are:

\[
E(v_{11}) = E[\xi_1 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{\xi_1^* \xi_2^*} \xi_1 + \rho_{\xi_2^* \xi_1^*} \xi_2 / \xi_1 > \Omega_1, \xi_2 > \Omega_2]
\]

\[
E(v_{12}) = E[\xi_1 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{\xi_1^* \xi_2^*} \xi_1 + \rho_{\xi_2^* \xi_1^*} \xi_1 / \xi_1 > \Omega_1, \xi_2 > \Omega_2]
\]

\[
E(v_{21}) = E[\xi_2 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{\xi_1^* \xi_2^*} \xi_2 + \rho_{\xi_2^* \xi_1^*} \xi_2 / \xi_1 > \Omega_1, \xi_2 > \Omega_2]
\]

\[
E(v_{22}) = E[\xi_2 > \Omega_1, \xi_2 > \Omega_2] = E[\rho_{\xi_1^* \xi_2^*} \xi_2 + \rho_{\xi_2^* \xi_1^*} \xi_2 / \xi_1 > \Omega_1, \xi_2 > \Omega_2]
\]

<table>
<thead>
<tr>
<th>Variables</th>
<th>Husbands</th>
<th>Wives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 12</td>
<td>Group 10</td>
</tr>
<tr>
<td>$\ln \bar{W}_1$</td>
<td>-5.243 (1.11)</td>
<td>-0.483 (0.19)</td>
</tr>
<tr>
<td>$\ln \bar{W}_2$</td>
<td>2.674 (1.26)</td>
<td>--</td>
</tr>
<tr>
<td>$AG_1$</td>
<td>0.078 (0.30)</td>
<td>-0.041 (0.17)</td>
</tr>
<tr>
<td>$AG_1^2$</td>
<td>-0.001 (0.30)</td>
<td>-0.000 (0.12)</td>
</tr>
<tr>
<td>$ED_1$</td>
<td>0.166 (0.71)</td>
<td>0.152 (0.86)</td>
</tr>
<tr>
<td>$ED_2$</td>
<td>-0.308 (1.32)</td>
<td>0.116 (0.96)</td>
</tr>
<tr>
<td>$D(FRAISED_1)$</td>
<td>-0.116 (0.23)</td>
<td>-0.757 (1.27)</td>
</tr>
<tr>
<td>$K_1$</td>
<td>0.753 (1.28)</td>
<td>-0.707 (1.64)</td>
</tr>
<tr>
<td>$K_2$</td>
<td>0.062 (0.20)</td>
<td>-0.223 (0.84)</td>
</tr>
<tr>
<td>$K_3$</td>
<td>0.290 (1.69)</td>
<td>0.193 (1.29)</td>
</tr>
<tr>
<td>CITY</td>
<td>-0.003 (0.06)</td>
<td>-0.062 (1.41)</td>
</tr>
<tr>
<td>CITY$^2$</td>
<td>0.000 (0.13)</td>
<td>0.001 (1.18)</td>
</tr>
<tr>
<td>$\ln V_{OF}$</td>
<td>-0.021 (0.61)</td>
<td>0.008 (0.26)</td>
</tr>
<tr>
<td>GDD</td>
<td>-0.021 (0.61)</td>
<td>-0.001 (0.51)</td>
</tr>
</tbody>
</table>
Appendix B. Continued

<table>
<thead>
<tr>
<th>$\hat{G}<em>{ij}/\hat{P}</em>{ij}$</th>
<th>-0.011</th>
<th>-0.080</th>
<th>0.003</th>
<th>0.003</th>
</tr>
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<tr>
<td></td>
<td>(0.77)</td>
<td>(0.63)</td>
<td>(0.23)</td>
<td>(0.77)</td>
</tr>
<tr>
<td>$\hat{G}<em>{ij}/\hat{P}</em>{ij}$</td>
<td>0.001</td>
<td>0.016</td>
<td>0.001</td>
<td>-0.000</td>
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<tr>
<td></td>
<td>(0.21)</td>
<td>(0.52)</td>
<td>(0.33)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.31</td>
<td>0.20</td>
<td>0.28</td>
<td>0.10</td>
</tr>
<tr>
<td>$n$</td>
<td>60</td>
<td>93</td>
<td>60</td>
<td>112</td>
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